

LOCATION Chicago Office
TO David W. Miller
FROM John R. Thene
SUBJECT Sylvan Lake Watershed Modelling

DATE June 10, 1991

SYLVAN LAKE ENHANCEMENT PROJECT: PHASE II NON-POINT SOURCE POLLUTION MODEL RESULTS

SUMMARY

This report documents nonpoint source pollution computer modelling of the Sylvan Lake watershed. The modelling is focused on sediments and nutrients which can be detrimental to lake water quality. We modelled the Sylvan Lake watershed using the U.S. Department of Agriculture's AGricultural-Non-Point Source pollution model, AGNPS. This sort of modelling is useful in determining sources and relative quantities of pollutants eroded from agricultural lands. We determined inputs to Sylvan Lake of sediment, sediment-bound phosphorus, and dissolved phosphorus using the model and some interpretation of the AGNPS model results. The AGNPS model is storm-based; these quantities were determined for storms having one-, two-, five-, ten-, and twenty-five-year return intervals. Using these results we determined that the best prospective site for a wetland on Henderson Lake Ditch would be upstream of 850 North Road (See Figure 3).

The wetland location proposed in the feasibility study (Crisman, 1990) was rejected due to its proximity to existing wetlands and the difficulty of construction in such areas. Of the 33.8 square mile Sylvan Lake watershed, about 24.2 square miles, drains to Henderson Lake Ditch upstream of 850 North Road. Approximately 94 percent of the sediment, and 92 percent of the sediment-bound phosphorus, tributary to Henderson Lake Ditch is generated upstream of 850 North Road. A wetland located there has the potential to reduce the total sediment loading to Sylvan Lake by about 70 percent, sediment-bound phosphorus by about 70 percent, and total phosphorus by about 45 percent. These figures assume 100 percent trapping at the site; a lower percentage will actually occur depending upon the design layout. If this site is not available, a wetland located upstream of 800 North Road would cause only a small reduction in the trapping potential, however, we do not recommend that the wetland be located any further upstream.

The proposed site would leave some inflows to Sylvan Lake untreated. In some of these areas and areas upstream of Henderson Lake Ditch, lakes located on tributary streams provide excellent trapping of sediments. Best Management Practices (BMP's) are recommended for agricultural land in areas of the Sylvan Lake watershed not tributary to

lakes or the proposed site. BMP's combined with the proposed wetland would provide reduction of nutrient loadings from all subwatersheds tributary to Sylvan Lake.

PURPOSE

The AGNPS watershed model was used to determine potential nutrient loadings to Sylvan Lake, sources of those nutrients, and effective sites for construction of a wetland to retain sediments from watershed run-off. Once a wetland is designed and its effectiveness is evaluated, the results of the modelling can be used to determine potential changes in loading to the Lake.

AGNPS COMPUTER MODEL BACKGROUND

The AGricultural Non-Point-Source pollution computer model, AGNPS, was developed by the U.S. Department of Agriculture's Agricultural Research Service (USDA-ARS, 1987) for the evaluation of small agricultural watersheds. The model is a tool to determine soil and nutrient loss rates and to evaluate the effects of agricultural practices on loading to streams and water bodies receiving run-off from cropland. The model is a storm-based model, i.e. it computes rainfall runoff volume, soil loss, soil yield, phosphorus and other output for individual storms rather than an annualized basis. Because lakes respond to nutrient loadings on a longer time scale, the model cannot be used to directly evaluate lake response to watershed changes.

The AGNPS model works on a cell basis; that is, a watershed area is broken down into several square cells. An example cell layout for a subwatershed of Sylvan Lake is shown in Figure 1. The arrows on the watershed indicate the drainage patterns, and shaded areas indicate areas of standing water. Forty-acre cells, 1320-feet square, were used in the case of Sylvan Lake. This cell size is standard for AGNPS modeling. The model first computes soil loss, phosphorus, nitrogen and chemical oxygen demand (COD) for each cell. The soil loss portion of the model is based on the Universal Soil Loss Equation (USLE). Most of the dissolved constituents in the runoff are carried all the way to the watershed outlet. But sediment, and sediment-bound nutrients, can be deposited on flatter streambeds and eroded from steeper streambeds. Therefore significantly less soil can be delivered to the watershed outlet than the total of the soil losses from individual cells. The next step the model takes is to determine a sediment and nutrient "routing" for the watershed. Routing allows for the deposition and erosion of sediments in streams. The routing is carried out along the natural drainage patterns of the watershed, but in a step-wise manner from cell to cell.

MODEL INPUT DATA REQUIREMENTS

AGNPS requires a rainfall amount for the storm of interest, and the associated rainfall intensity which is the driving forces of soil loss. The model watershed data requires input of 22 parameters for each cell of the watershed. These can be broken into four groups: Data related to topography, data related to soil types, data related to land use, and data related to crop and land management practices.

MODEL INPUT DATA SOURCES

Rainfall amounts for the one-, two-, five-, ten-, and twenty-five year, 24-hour, storms were determined for the Sylvan Lake area from the Weather Bureau rainfall frequency information for Indiana (US Dept. Comm, Weather Bureau, 1961). The energy-intensity values were determined for an Soil Conservation Service Type-II storm by the standard methods.

Topographic data, including land slope, were taken from U.S. Geological Survey topographic maps of the watershed. Dominant soil types for each cell were determined from maps provided in the Noble County Soil Survey (USDA, Soil Conservation Service, 1977). Soil properties, including soil erodibility, used in the AGNPS model were provided by the Noble County office of the SCS (Bortner, 1991). Land use was determined from the aerial photographs in the soil survey, and the model parameters based on land use were taken from the AGNPS model documentation (USDA, Agricultural Research Service, 1987). Input data related to crop and land management practices were determined from information provided by the Noble County SCS.

APPLICATION OF AGNPS TO SYLVAN LAKE WATERSHED

The most recent version of the AGNPS model (Version 3.51) was used to model the Sylvan Lake watershed. The Sylvan Lake watershed is shown in Figure 3 and has a surface area of 33.8 square miles. The Sylvan Lake watershed was broken into eleven subwatersheds, and as shown in Figure 3, includes several lakes and perennial streams. Table 1 provides a description of each of the subwatersheds, including area, the average annual runoff based on the a nearby USGS stream gage, and the area, volume, and residence time, or flushing time, for each of the major lakes in the watershed.

The nature and size of the Sylvan Lake watershed did not allow for straightforward application of the AGNPS model. The presence of lakes and perennial streams within the watershed required special procedures to make the results meaningful. Lakes and perennial

streams located within the watershed affect the amounts of soil and nutrients transported in the streams.

The lakes in the watershed which have significant effects on Sylvan Lake sediment and nutrient loadings are Latta, Wible, Little Long, Round and Bixler Lakes. Henderson Lake also affects nutrient loadings due to the Kendallville wastewater treatment plant discharge, but does not influence the AGNPS modelling. (The effect of Henderson Lake is not necessary to this portion of our studies. Its affect can be assessed in parallel to the AGNPS results.) Other smaller lakes exist in the watershed, but do not affect the AGNPS model significantly. Perennial streams in the watershed include Oviatt Ditch which drains Latta and Wible Lakes; Henderson Lake Ditch which drains Henderson Lake, Waterhouse Ditch, and Bixler Lake Ditch; Waterhouse Ditch which drains Little Long and Round Lakes; and Bixler Lake Ditch which drains Bixler Lake. All of these major streams drain to the Gravel Pit Basin of Sylvan Lake.

Areas tributary to upstream lakes were not modeled using AGNPS. This resulted in a large avoided cost and provided a better result than if AGNPS were used. If AGNPS were used, modelling of the in-lake processes would have been necessary to determine outflow concentrations. This would have become an expensive and time-consuming endeavor which might only result in erroneous or uncertain results. Sediment and phosphorus loadings were of main importance in the Sylvan Lake watershed study. Special consideration was given to the effect of upland lakes on the transport and fate of sediment and phosphorus.

First, lakes can act as highly effective sediment traps because of their depth and volume. When water slows as in lakes or wetlands, sediments generally deposit there, and waters leaving these areas are generally free of sediment. Therefore, we determined that the amount of sediment, and sediment bound phosphorus, in the lake discharges would be negligible compared to that yielded from areas downstream of the lakes. Second, lake outflow phosphorus concentrations are dependent primarily on the existing concentrations in the lake before a storm event. This is because water generally exits a lake far from the point which it enters, and in most cases the discharge from the lake is from the surface. And due to sediment loads, inflows most often plunge to the bottom of a lake. In the Sylvan Lake watershed modelling, upland lake outflow volumes were proportioned to the runoff volume of areas modelled using AGNPS. Outflow dissolved phosphorus concentrations were determined from historical data. The lakes proved to be insignificant sources of nutrients, relative to other loadings to Sylvan Lake.

The modelling of the Sylvan Lake watershed is depicted schematically in Figure 3. The subwatersheds, lakes and major streams are depicted along with the routes of water, sediments and nutrients. Subwatersheds 3, 6, 9, 10, and 11 are upstream of lakes and therefore were not modeled using AGNPS. Figures 2 and 3 show that most of the watershed is tributary to the Gravel Pit Basin of Sylvan Lake. Subwatershed 1 includes the

areas around the perimeter of Sylvan Lake and portions of it feed each of the four basins of Sylvan Lake (Figure 2). The AGNPS cell layouts for Subwatersheds 1, 2, 4, 5, 7, and 8 are shown in Figures 4a-f.

Another complication of the modelling effort was that AGNPS is not capable of correctly modelling sediment routing through perennial streams. This was communicated to us by the SCS AGNPS Liaison (Finney, 1991) at the Indianapolis, IN meeting of the IDNR T by 2000 Lake Enhancement Program and AGNPS instruction this spring. Because of this limitation, we determined the most appropriate modification would be to assume that all sediment, and sediment-bound phosphorus, that reached perennial streams would be transported all the way to Sylvan Lake. This assumption does not allow for any erosion or deposition in perennial streams. Although this assumption may not be strictly correct for any given storm event, it is appropriate to consider that in the long term, the stream bed does not change substantially. This method is sufficient for lakes as they respond to nutrient loadings on long-term bases.

Upland lake contributions to dissolved phosphorus also presented a problem for the AGNPS model. Our original intention was to model the lakes as point source inflows within the AGNPS model structure. After testing this approach, it was determined that the AGNPS model gave unreasonable results in terms of peak runoff rate, total runoff, and total dissolved nutrients. The model does not accurately handle large point source inflows.

In order to incorporate the assumption of no erosion/no deposition in the streams, and the upland lake contributions to runoff and dissolved phosphorus, we developed a spreadsheet to route the runoff, sediments, and sediment-bound phosphorus, and dissolved phosphorus. For the constituents which reach perennial streams in overland runoff and from lakes, we extracted the appropriate data from the AGNPS computer output and entered it into our spreadsheet program. The spreadsheet computed total loadings along the streams in each of the subwatersheds modeled with AGNPS, including upstream loadings to each of the subwatersheds.

RESULTS

The condensed AGNPS model results, in the form of our spreadsheet routings, are presented in Appendix A. For each subwatershed, the Appendix A tables show the subwatershed (or basin of Sylvan Lake) which it is tributary to, its area, and the area computed by AGNPS (sink holes in the watersheds cause an apparent reduction in watershed area). And, for storm runoff, sediment, dissolved phosphorus, and sediment phosphorus, the tables show the yield from each subwatershed and the total routed to that point. The total routed includes the yield from the subwatershed and all areas upstream of it.

Plots of sediment and sediment-bound phosphorus loadings versus distance along Henderson Lake Ditch, Figure 5, were made for use in determining the best location for the wetland. Henderson Lake Ditch carries the majority of runoff to Sylvan Lake and the plots provide a good summary of the loadings along the ditch. The first vertical line of the plots indicate the loadings from Subwatersheds 7 and 8, which are input to Henderson Lake Ditch at the upstream end of Subwatershed 5. The plots then show the increase in total loadings along the length of Henderson Lake Ditch to Sylvan Lake. Finally, the last vertical line indicates the loadings from Subwatersheds 1, 2 and 4, at the downstream end of Subwatershed 5. This gives the total loading to Sylvan Lake which is shown as a horizontal line at the end of the plot.

The plots of Figure 5 show that loadings for each storm are similar in shape, but the magnitude of the loadings increase with the size and intensity of the storm. This indicates that distribution of stream loadings along the ditch are nearly independent of storm size. This makes the selection of wetland sites simpler in that the optimal location determined from one storm event will be the same as for another.

POTENTIAL WETLAND SITES

The 1990 feasibility study (Crisman, 1990) proposed that the wetland at the inlet to Gravel Pit Basin be expanded or modified to allow it to trap incoming sediments from Henderson Lake Ditch. This site is not recommended due to potential difficulties associated with construction in the wetland. Further, that area is flat and high in relation to Latta Lake. The elevation of Sylvan Lake is about 916 feet above mean sea level whereas the elevation of Latta Lake is about 920. Therefore, an expanded wetland may cause a very large area to be inundated near Latta Lake.

Henderson Lake Ditch delivers the majority of sediments to Sylvan Lake. Therefore a suitable alternative to the site proposed in the feasibility study could be on Henderson Lake Ditch, upstream of that wetland area. In any case, the loadings from Subwatershed 1 (the area immediately surrounding Sylvan Lake) could not be trapped because there are only small tributaries all around the perimeter of the lake. With a site on Henderson Lake Ditch, sediments from Subwatersheds 2, and 4 would also not be treated. (Subwatershed 2 is only 110 acres and has negligible loadings to Sylvan Lake.)

The proposed wetland site is upstream of 850 North Road. This site has a potential advantage that the road may be utilized as a dam and the only construction required would be an outlet structure and possibly some site grading. This location has the potential to trap about 56% of the sediments transported to Sylvan Lake, assuming that 80% of the sediments reaching the site are trapped. Of the total loadings reaching Sylvan Lake via Henderson Lake Ditch, only a small portion would reach the stream downstream of the site. This can be seen from the loading plots in Figure 5. For example, the computed sediment

loadings from the one-year storm are 788 tons at the proposed site, 842 tons at the mouth of Henderson Lake Ditch, 972 tons at the inlet to Gravel Pit Basin, and 1113 tons total to Sylvan Lake including loadings from Subwatershed 1. Therefore, of the 842 tons that could be affected by a wetland located on Henderson Lake Ditch, 788 tons can be affected by a wetland at 850 Road North. Relative reductions in sediment-bound phosphorus would be about the same, but there is also dissolved phosphorus in the runoff water. Therefore the total phosphorus to Sylvan Lake would be reduced by about 35 to 40 percent again assuming 80 percent sediment removal.

If this site is not available, or not feasible for other reasons, the site could be moved upstream to 800 North Road. At this location less of the sediment and phosphorus would be treated than at 850 North Road. The amount of sediment and sediment phosphorus not treated because of moving the wetland from 850 North Road to 800 North Road can be seen in Figure 5, as indicated by the location of the roads on the plots.

The potential changes in loadings to Sylvan Lake are summarized in Table 2 and depicted for both sites in Figure 6. Figure 6 was developed assuming 80 percent trapping efficiency for sediment and sediment-bound phosphorus. Figures 6a and 6c show the sediment reaching each of the sites, the sediment reaching Sylvan without the wetland, and the sediment reaching Sylvan with the wetland. The reduction in loading can be seen from the last two bars. Figures 6b and 6d show the sediment phosphorus reaching each of the sites, the sediment phosphorus reaching Sylvan without the wetland, the total (sediment-bound and dissolved) phosphorus reaching Sylvan Lake without the wetland, and the total phosphorus reaching Sylvan with the wetland. The reduction in phosphorus loading can be seen from the last two bars.

OTHER POTENTIAL MITIGATIVE MEASURES

Harza recommends that Best Management Practices (BMP's) be employed on agricultural lands within the Sylvan Lake watershed. For Sylvan Lake, the most important areas to apply them will be areas whose runoff is not treated by the wetland, namely Subwatersheds 1 and 4.

REFERENCES

- Bortner, B., 1991. Data on Noble County soil properties, personal communication, February.
- Crisman, T. L., 1990. Sylvan Lake, Indiana: A final feasibility report, submitted to the Sylvan Lake Improvement Association, Inc., May.
- Finney, V., 1991. Personal communication at IDNR T by 2000 Program meeting at West Lafayette, IN, February.
- US Department of Agriculture - Agricultural Research Service, 1987. AGNPS, agricultural non-point-source pollution model: A watershed analysis tool. USDA-ARS Conservation Research Report 35, December.
- US Department of Agriculture - Soil Conservation Service, 1977. Soil survey of Noble County, Indiana, December.
- US Department of Commerce - Weather Bureau, 1961. USDC-WB Technical Paper 40.

LIST OF TABLES

- Table 1. Sylvan Lake subwatershed areas, run-off, and lake residence time.
- Table 2. Potential changes in sediment and sediment-bound phosphorus loadings to Sylvan Lake due to construction of wetlands on Henderson Lake Ditch.

SYLVAN LAKE IMPROVEMENT ASSOCIATION INDIANA DEPARTMENT OF NATURAL RESOURCES T by 2000 LAKE ENHANCEMENT PROGRAM			TABLE 1 SYLVAN LAKE SUB-WATERSHED AREAS, ANNUAL RUN-OFF AND LAKE RESIDENCE TIME			HARZA Engineering Company PROJ. No: 5256B DATE: APR 1991 FILE: SYLWSSUM.WK1		
SUB-WATERSHED						LAKES:		
No.	TRIB. TO SUB- WATER SHED No.	DESCRIPTION	AREA (AC)	AGNPS AREA (1) (AC)	ANNUAL RUNOFF (2) (AC-FT)	LAKE AREA (AC)	LAKE VOLUME (AC-FT)	LAKE RES. TIME(3) (YR)
TOTAL		TOTAL AREA TRIB TO SYLVAN LAKE	21660	-	23465	669	5989	0.26
1	SYLVAN LAKE	AREA AROUND SYLVAN PLUS LAKE AREA	2900	2920	3142			
2	SYLVAN LAKE	WETLAND UPSTREAM OF GRAVEL PIT BASIN, TAKES RUN-OFF FROM SUB-WATERSHEDS 3 THROUGH 11	110	120	20323			
3	2	AREA TRIBUTARY TO LATTA LAKE	1610	-	1744	42	900	0.52
4	2	AREA TRIBUTARY TO OVIATT DITCH DOWNSTREAM WIBLE LAKE	1140	1080	4593			
5	2	AREA TRIBUTARY TO HENDERSON LAKE DITCH DOWNSTREAM OF WATERHOUSE DITCH	2910	2960	13867			
6	4	AREA TRIBUTARY TO WIBLE LAKE	3100	-	3358	46	620	0.18
7	5	AREA TRIBUTARY TO WATERHOUSE DITCH FROM LITTLE LONG LAKE TO HENDERSON LAKE DITCH	810	720	4030			
8	5	HENDERSON LAKE DITCH, BIXLER LAKE DITCH	2780	2720	6684			
9	7	AREA TRIBUTARY TO LITTLE LONG LAKE	690	-	3153	71	1750	0.56
10	8	AREA TRIBUTARY TO BIXLER LAKE	3390	-	3673	120	2090	0.57
11	9	AREA TRIBUTARY TO ROUND LAKE	2220	-	2405	99	2140	0.89

NOTES:

(1) AGNPS MODEL AREAS BASED ON NUMBER OF 40--ACRE CELLS AND INCLUDES AREA IDENTIFIED AS SINK HOLES.

(2) BASED ON AVERAGE RUN-OFF OF 13 INCHES PER YEAR FROM NEARBY STREAM GAGE AND FIGURES INCLUDE RUN-OFF FROM UPSTREAM SUB-WATERSHEDS.

(3) LAKE VOLUME DIVIDED BY TOTAL ANNUAL RUN-OFF TO LAKE.

SYLVAN LAKE IMPROVEMENT ASSOCIATION
INDIANA DEPT OF NATURAL RESOURCES
T by 2000 LAKE ENHANCEMENT PROGRAM

TABLE 2
POTENTIAL EFFECT OF
PROPOSED WETLAND ON
SEDIMENT AND PHOSPHORUS
LOADINGS TO SYLVAN LAKE

HARZA Engineering Company

PROJ. No: 5256B
DATE: MAY 1991
FILE: SEDBAR2.WK3

WETLAND SITE:
850 NORTH ROAD

STORM RETURN INTERVAL // RAINFALL (YR // IN)	ASSUMED TRAP EFFICIENCY (1)	SEDIMENT				PHOSPHORUS				
		ROUTED TO SITE	ROUTED TO SYLVAN			SEDIMENT ATTACHED		TOTAL PHOSPHORUS TO SYLVAN (SEDIMENT PLUS DISSOLVED)		
			WITHOUT WETLAND	WITH WETLAND	PERCENT REDUCTION	ROUTED TO SITE	ROUTED TO SYLVAN	WITHOUT WETLAND	WITH WETLAND	PERCENT REDUCTION
		(T)	(T)	(T)		(LB)	(LB)	(LB)	(LB)	
1 // 2.3	80%	788	1113	483	56.6%	1438	2082	3269	2119	35.2%
2 // 2.7	80%	1090	1552	680	56.2%	1874	2724	4089	2590	36.7%
5 // 3.4	80%	1890	2699	1187	56.0%	2924	4278	5900	3561	39.6%
10 // 3.9	80%	2620	3758	1662	55.8%	3796	5581	7346	4309	41.3%
25 // 4.4	80%	3497	5032	2234	55.6%	4798	7096	9001	5163	42.6%

WETLAND SITE:
800 NORTH ROAD

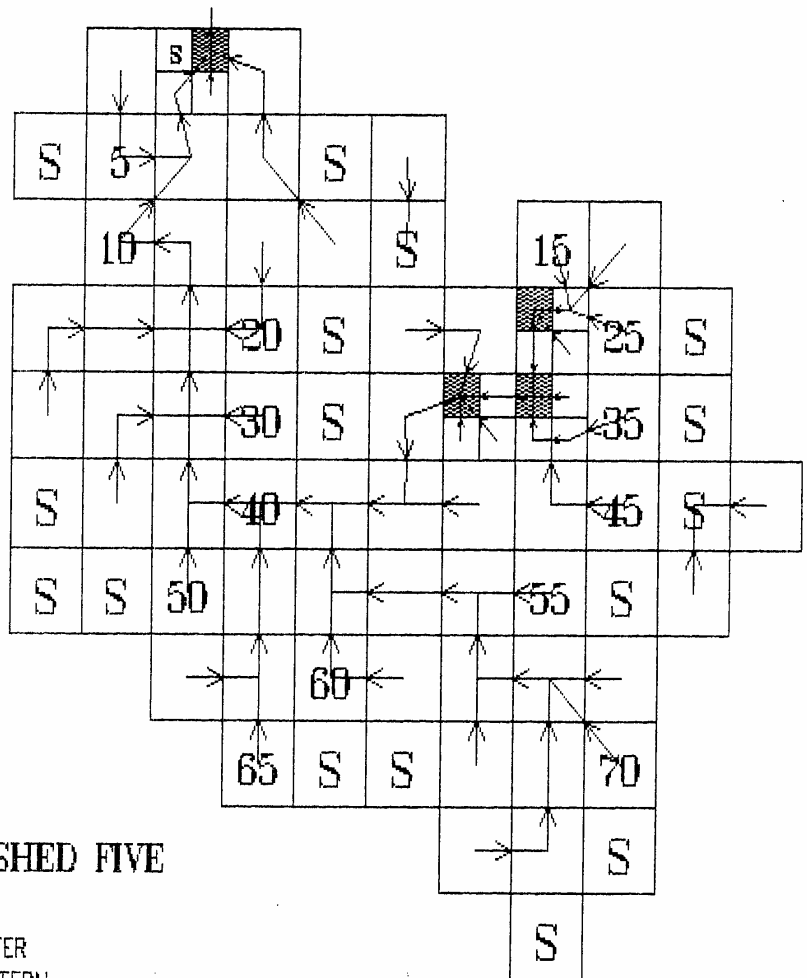
STORM RETURN INTERVAL // RAINFALL (YR // IN)	ASSUMED TRAP EFFICIENCY (1)	SEDIMENT				PHOSPHORUS				
		ROUTED TO SITE	ROUTED TO SYLVAN			SEDIMENT ATTACHED		TOTAL PHOSPHORUS TO SYLVAN (SEDIMENT PLUS DISSOLVED)		
			WITHOUT WETLAND	WITH WETLAND	PERCENT REDUCTION	ROUTED TO SITE	ROUTED TO SYLVAN	WITHOUT WETLAND	WITH WETLAND	PERCENT REDUCTION
		(T)	(T)	(T)		(LB)	(LB)	(LB)	(LB)	
1 // 2.3	80%	690	1113	561	49.6%	1251	2082	3269	2268	30.6%
2 // 2.7	80%	947	1552	794	48.8%	1621	2724	4089	2792	31.7%
5 // 3.4	80%	1626	2699	1398	48.2%	2513	4278	5900	3690	34.1%
10 // 3.9	80%	2246	3758	1961	47.8%	3253	5581	7346	4744	35.4%
25 // 4.4	80%	2989	5032	2641	47.5%	4104	7096	9001	5718	36.5%

NOTES:

(1) SEDIMENT TRAP EFFICIENCY OF WETLANDS ASSUMED. ACTUAL EFFICIENCY WILL DEPEND ON ACTUAL DESIGN LAYOUT.

LIST OF FIGURES

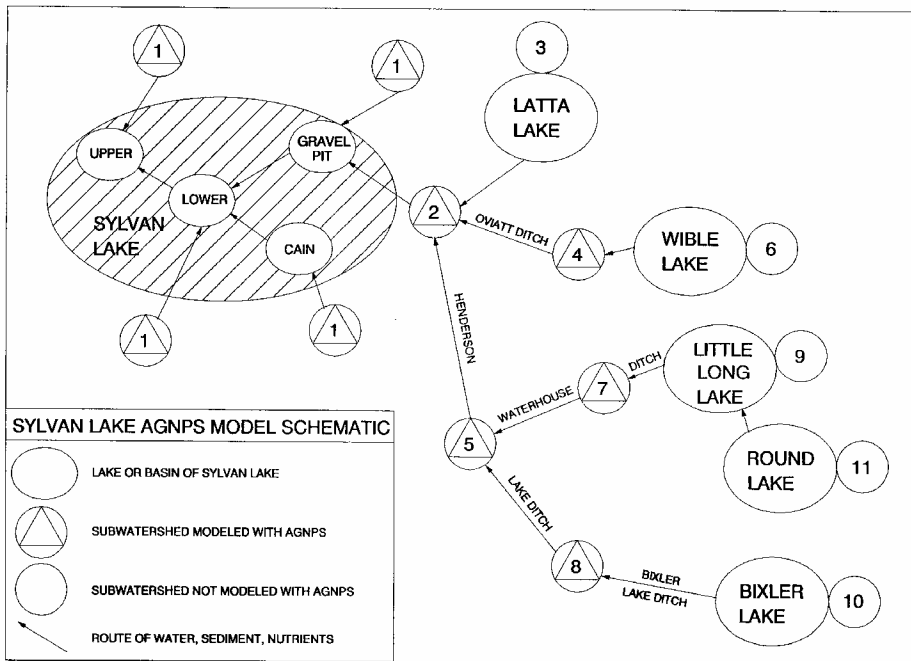
- Figure 1. Example AGNPS cell layout.
- Figure 2. Map of Sylvan Lake watershed.
- Figure 3. Schematic drawing of Sylvan Lake watershed modelling.
- Figure 4. Layout of cells and drainage paths for areas modelled with AGNPS.
- Figure 5. Sediment and sediment-bound phosphorus loadings to Sylvan Lake as accumulated along Henderson Lake Ditch in Subwatershed 5.
- Figure 6. Potential changes in sediment and sediment-bound phosphorus loadings to Sylvan Lake due to construction of wetlands on Henderson Lake Ditch.



SUBWATERSHED FIVE

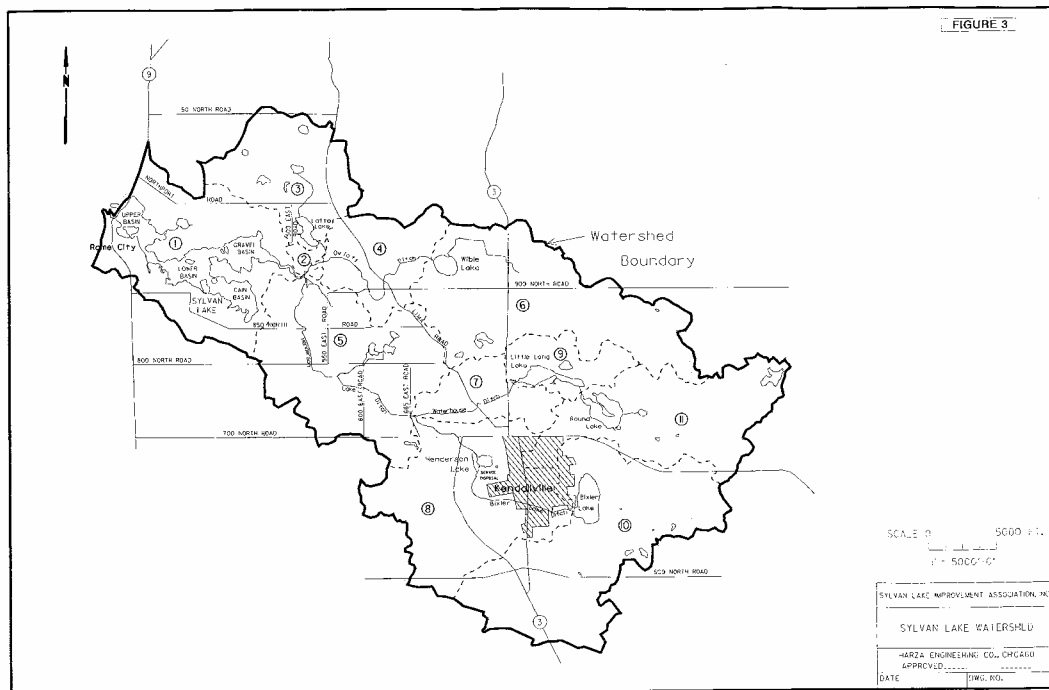
Figure 1.

Example layout of AGNPS cells (40-acre cells with some subdivided to 10 acres) and drainage paths for Subwatershed 5. Numbers indicate cell numbering sequence, arrows show direction of drainage, shaded areas indicate water and "S" indicates areas which do not drain, or "sinks."



HARZA Engineering Company

FIGURE 2



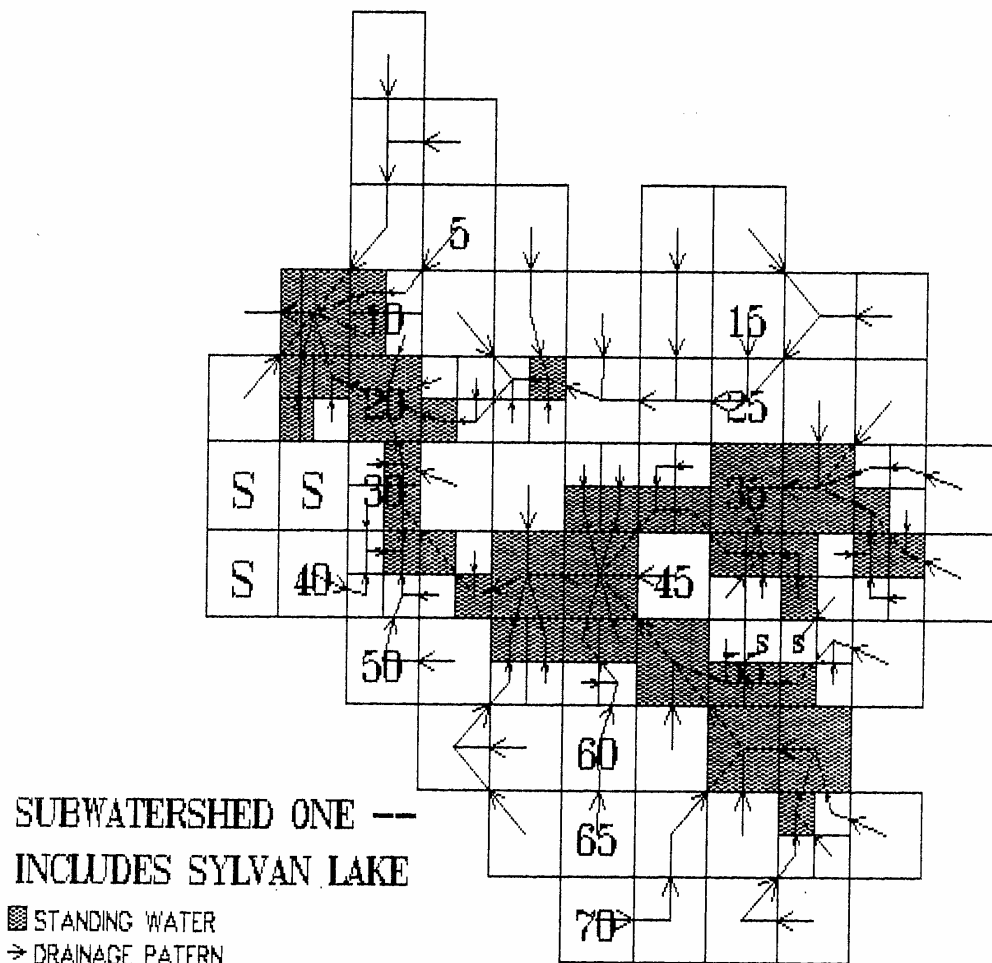


Figure 4a.

Layout of AGNPS cells (40-acre cells with some subdivided to 10 acres) and drainage paths for Subwatershed 1. Numbers indicate cell numbering sequence, arrows show direction of drainage, shaded areas indicate water and "S" indicates areas which do not drain, or "sinks."

SUBWATERSHED TWO

→ DRAINAGE PATTERN

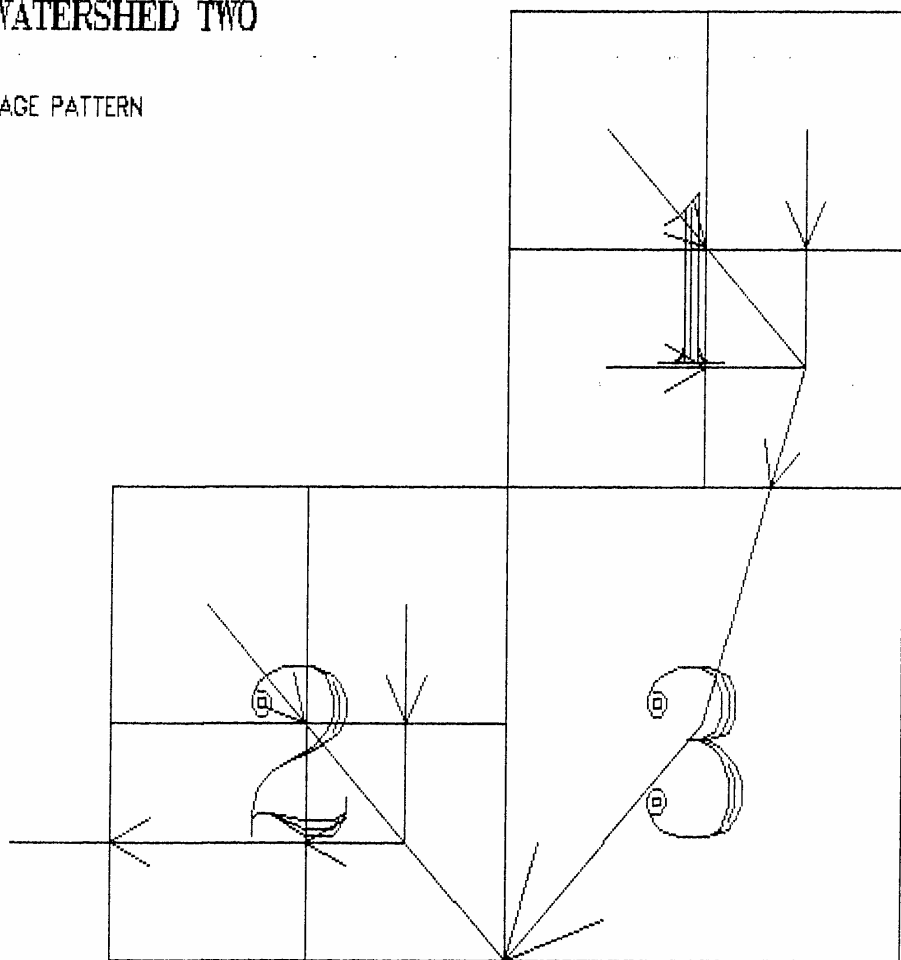


Figure 4b.

Layout of AGNPS cells (40-acre cells with some subdivided to 10 acres) and drainage paths for Subwatershed 2. Numbers indicate cell numbering sequence and arrows show direction of drainage.

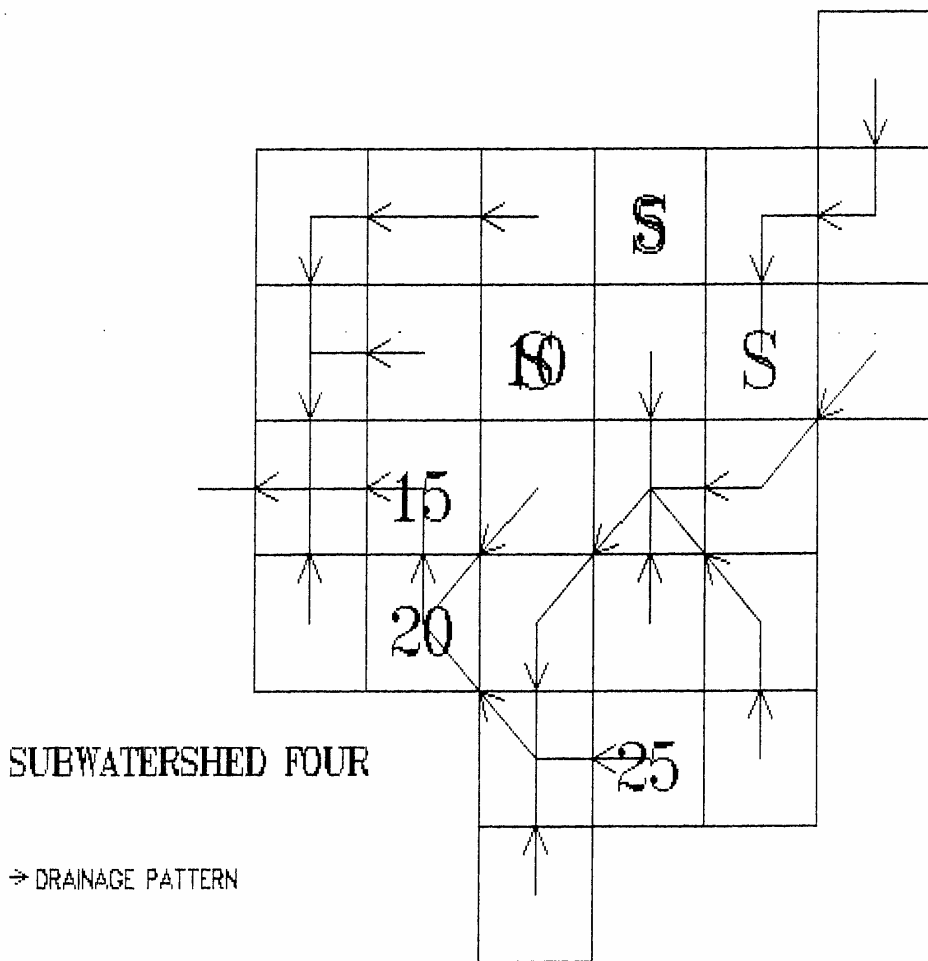


Figure 4c.

Layout of AGNPS cells (40-acre cells) and drainage paths for Subwatershed 4. Numbers indicate cell numbering sequence, arrows show direction of drainage and "S" indicates areas which do not drain, or "sinks."

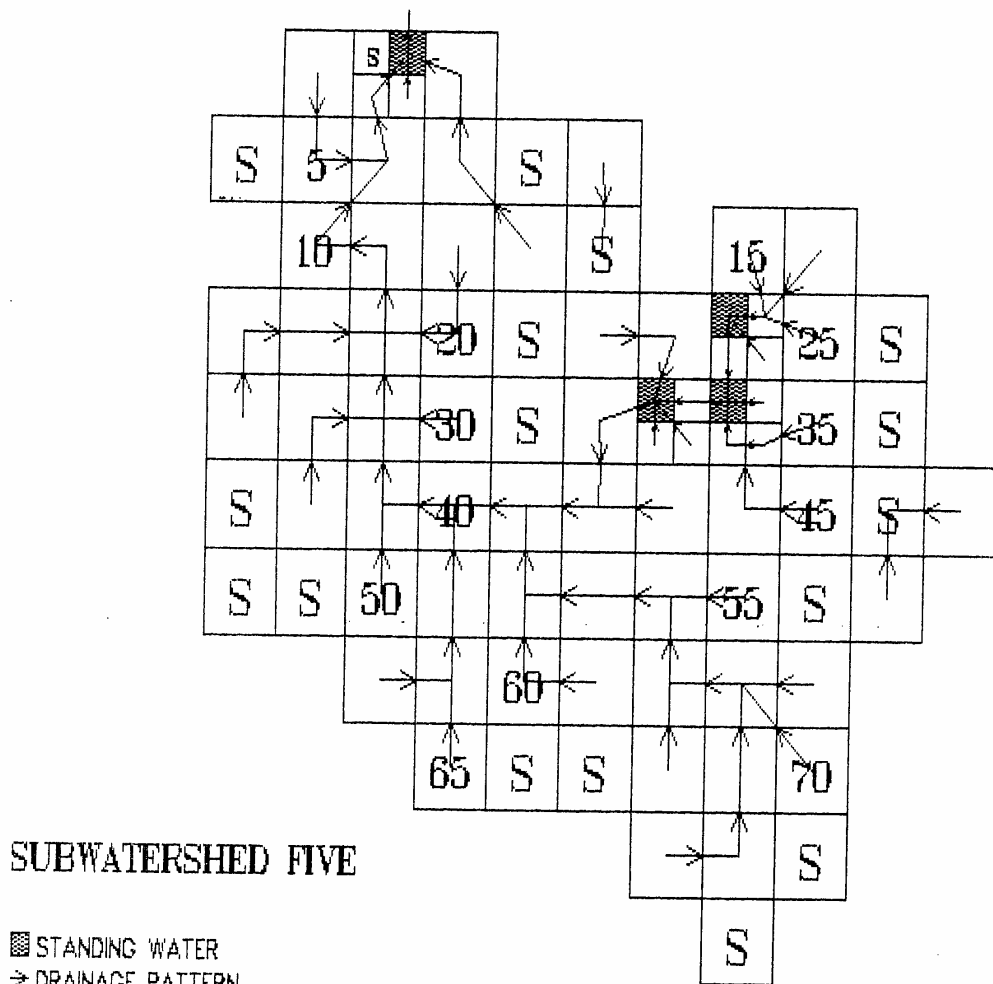
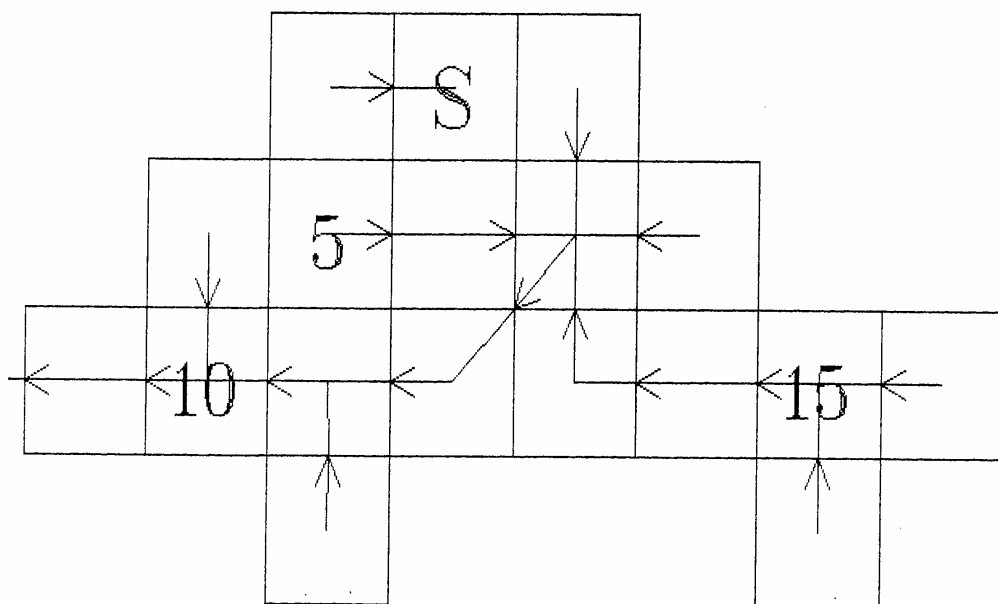


Figure 4d.

Layout of AGNPS cells (40-acre cells with some subdivided to 10 acres) and drainage paths for Subwatershed 5. Numbers indicate cell numbering sequence, arrows show direction of drainage, shaded areas indicate water and "S" indicates areas which do not drain, or "sinks."



SUBWATERSHED SEVEN

→ DRAINAGE PATTERN

Figure 4e.

Layout of AGNPS cells (40-acre cells) and drainage paths for Subwatershed 7. Numbers indicate cell numbering sequence, arrows show direction of drainage and "S" indicates areas which do not drain, or "sinks."

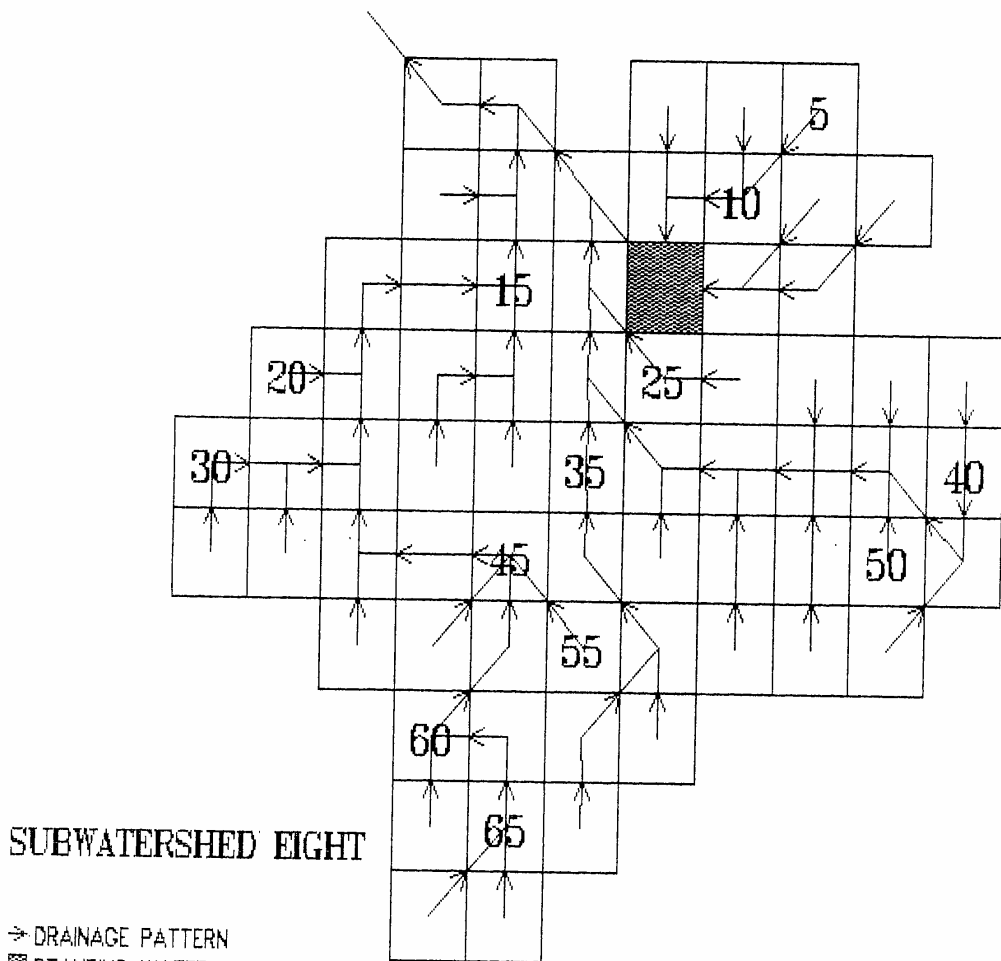


Figure 4f.

Layout of AGNPS cells (40-acre cells with some subdivided to 10 acres) and drainage paths for Subwatershed 8. Numbers indicate cell numbering sequence, arrows show direction of drainage, and shaded areas indicate water.

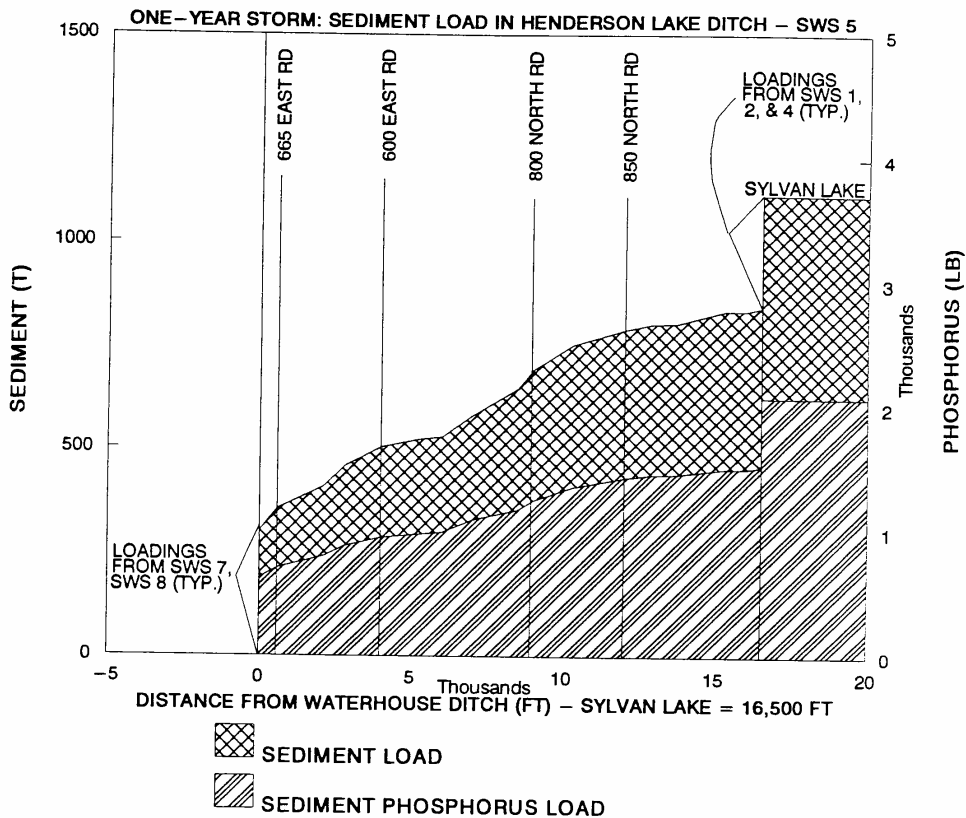


Figure 5a.

Sediment and sediment-bound phosphorus loadings to Sylvan Lake as accumulated along Henderson Lake Ditch in Subwatershed 5 for one-year storm.

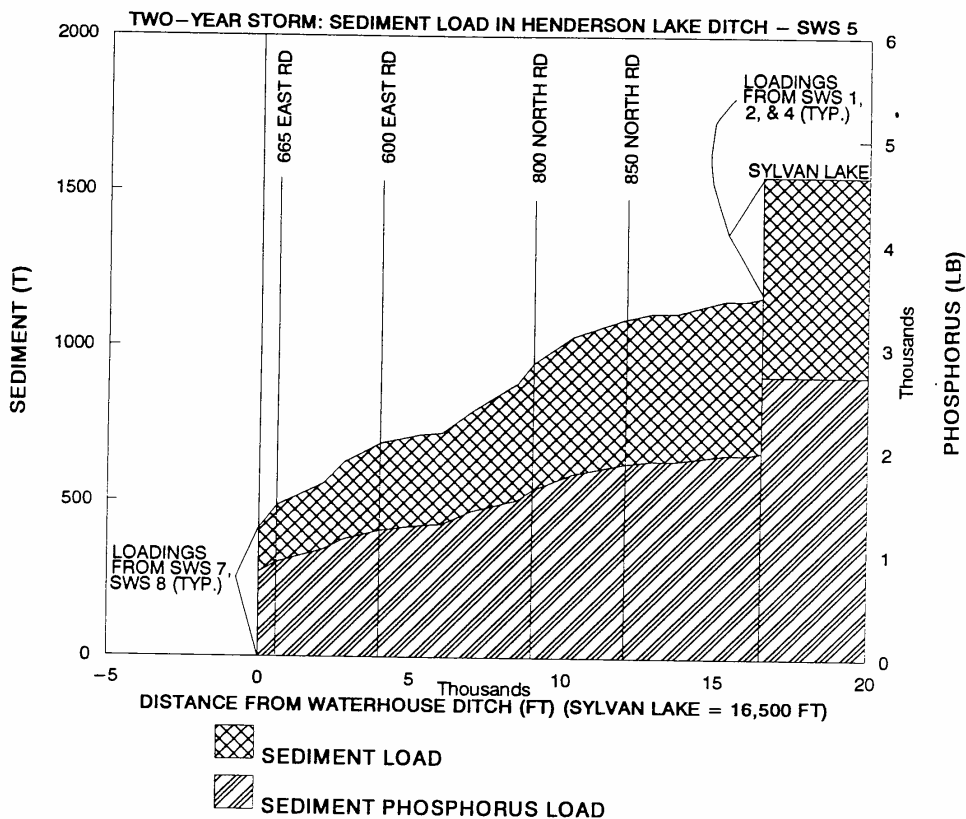


Figure 5b.

Sediment and sediment-bound phosphorus loadings to Sylvan Lake as accumulated along Henderson Lake Ditch in Subwatershed 5 for two-year storm.

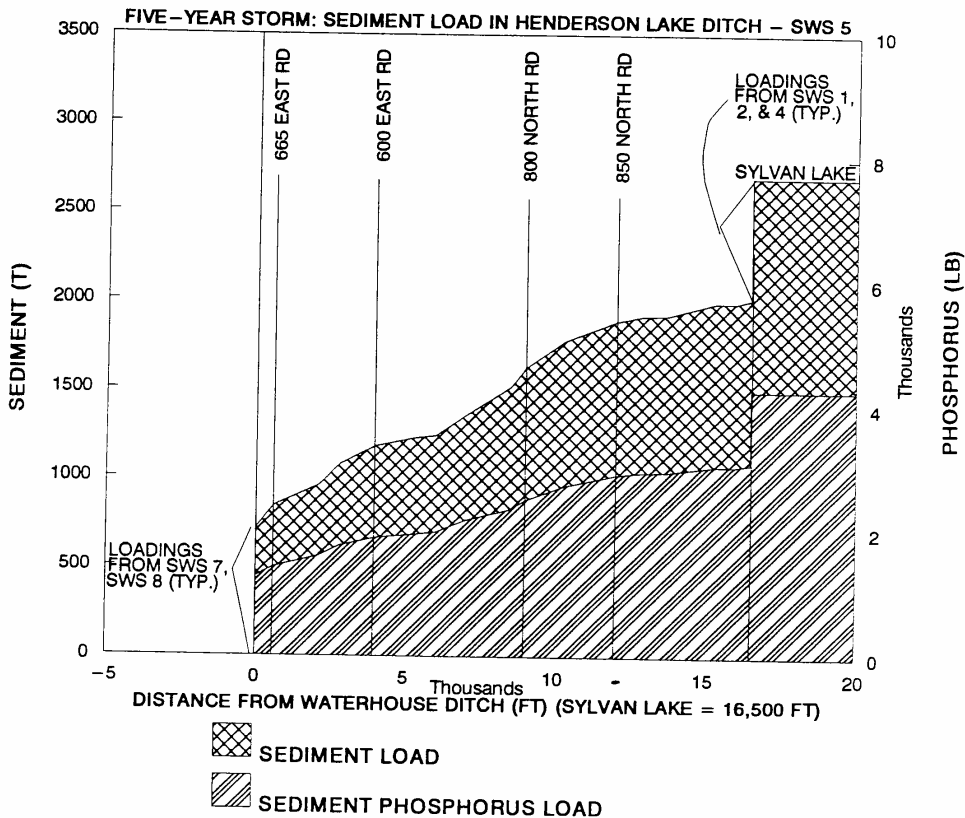


Figure 5c.

Sediment and sediment-bound phosphorus loadings to Sylvan Lake as accumulated along Henderson Lake Ditch in Subwatershed 5 for five-year storm.

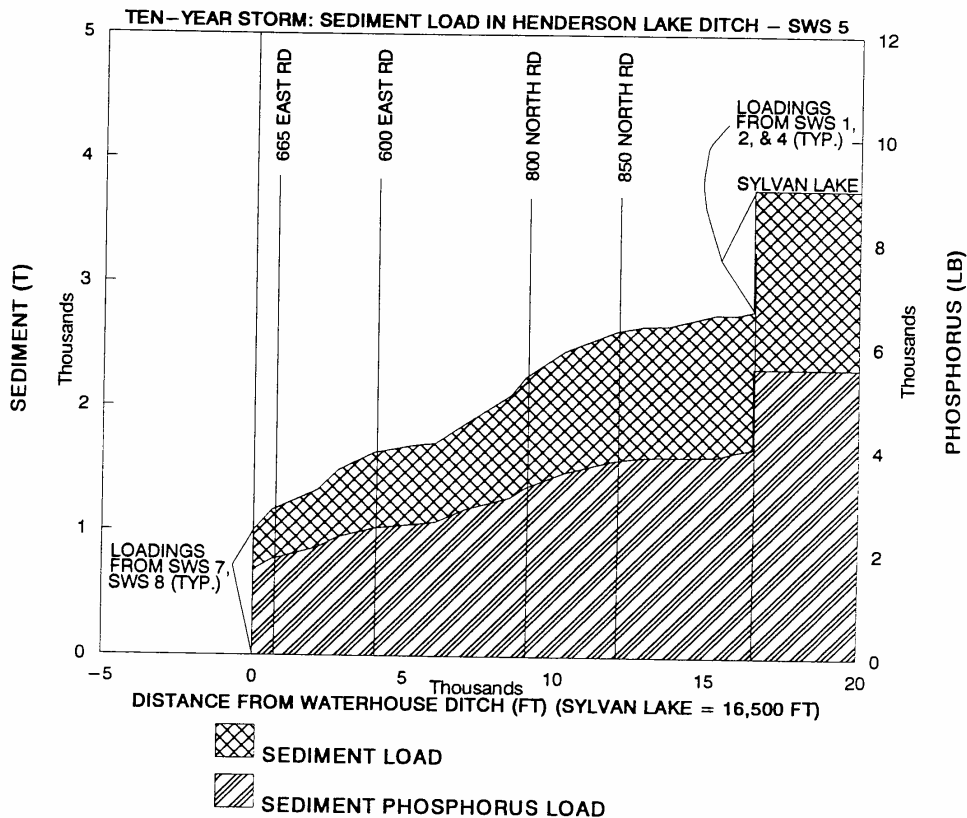


Figure 5d.

Sediment and sediment-bound phosphorus loadings to Sylvan Lake as accumulated along Henderson Lake Ditch in Subwatershed 5 for ten-year storm.

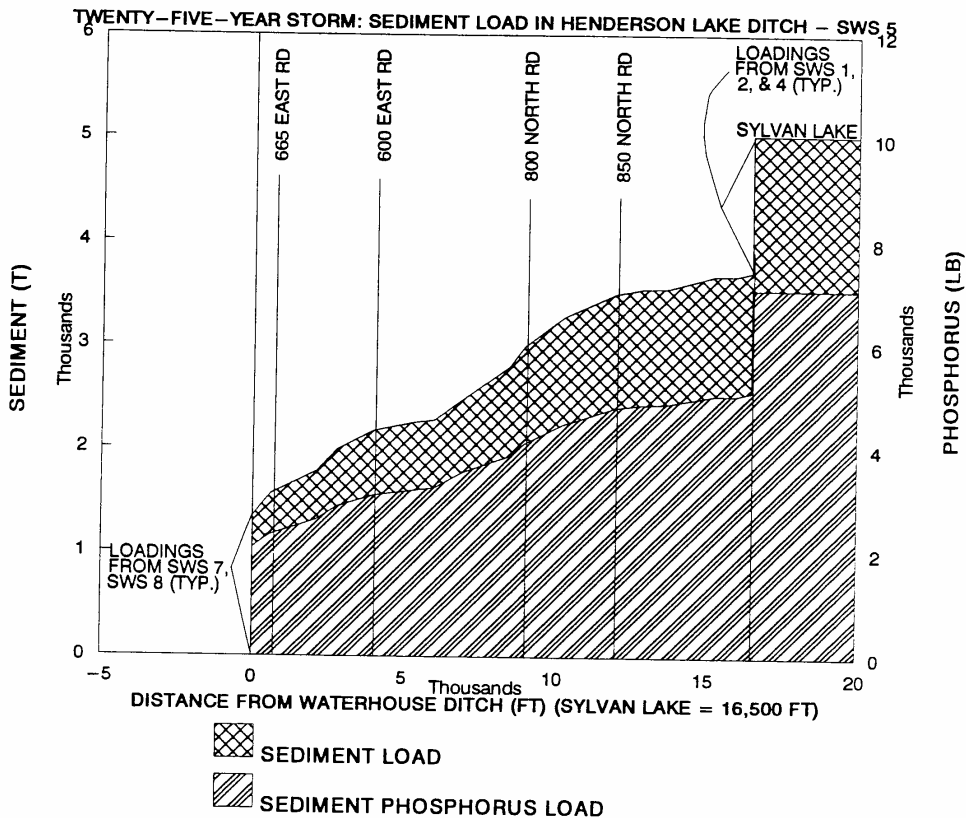


Figure 5e.

Sediment and sediment-bound phosphorus loadings to Sylvan Lake as accumulated along Henderson Lake Ditch in Subwatershed 5 for twenty-five-year storm.

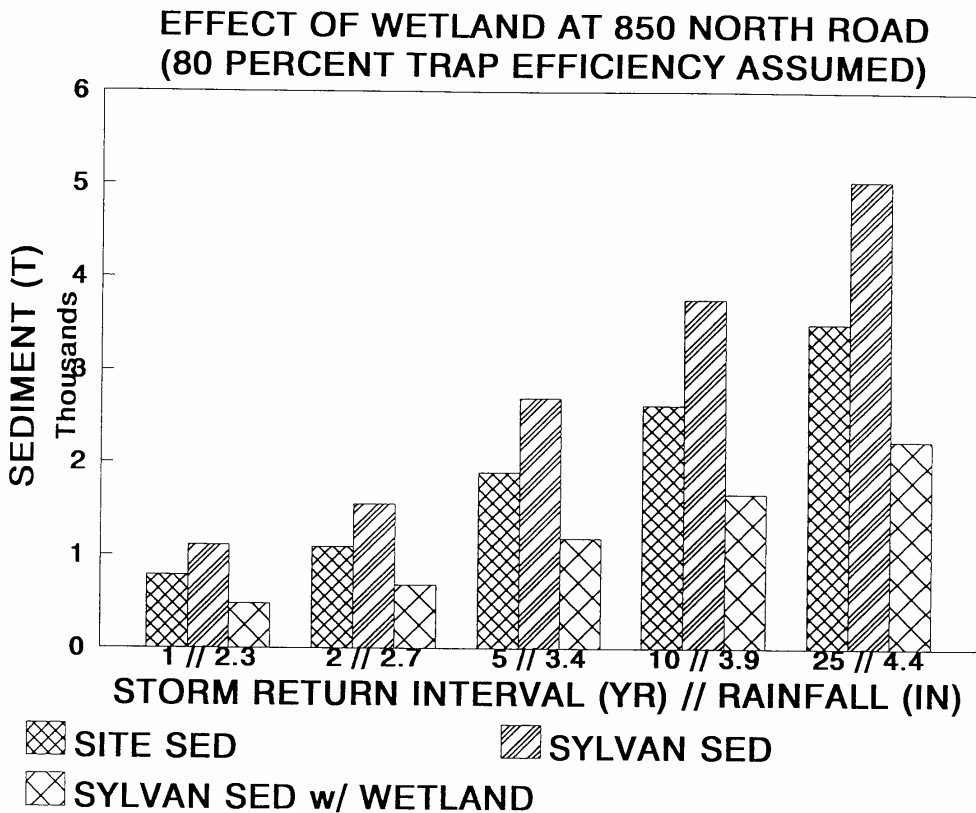


Figure 6a.

Potential changes in sediment loadings to Sylvan Lake due to construction of wetlands on Henderson Lake Ditch at 850 North Road where:

SITE SED = sediment load at proposed site;

SYLVAN SED = sediment load delivered to Sylvan Lake before wetland development;

SYLVAN SED w/ WETLAND = sediment load delivered to Sylvan Lake with wetland developed at proposed site which traps 80 percent of incoming sediments.

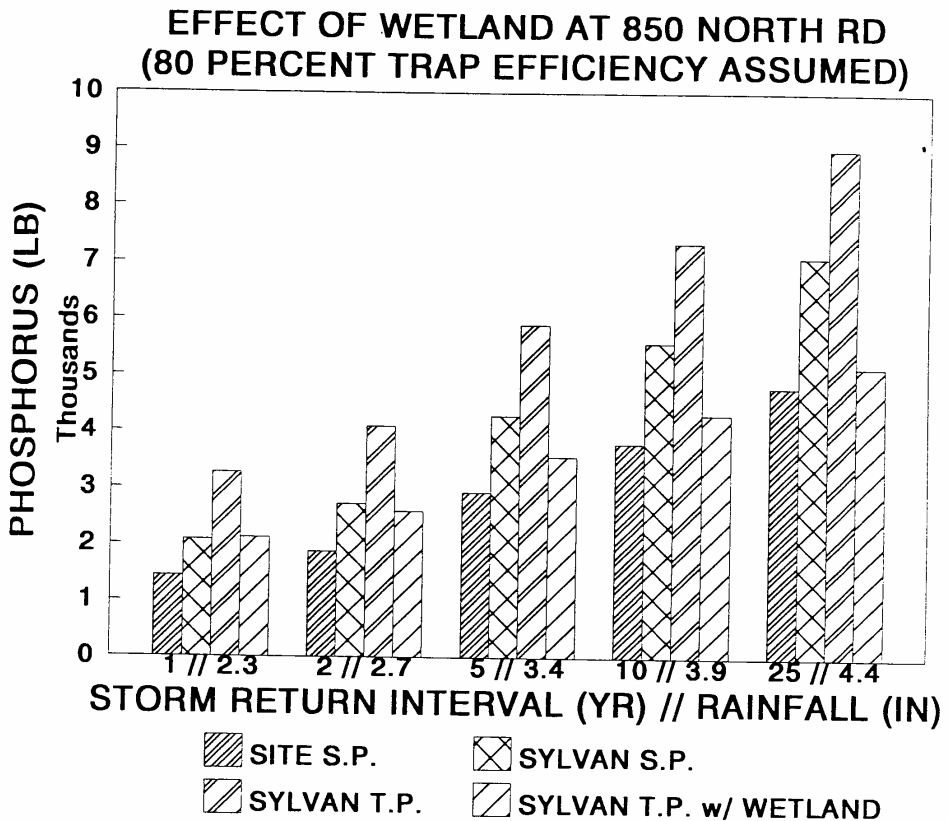


Figure 6b.

Potential changes in phosphorus loadings to Sylvan Lake due to construction of wetlands on Henderson Lake Ditch at 850 North Road where:

SITE S.P. = sediment-bound phosphorus load at proposed site;

SYLVAN S.P. = sediment-bound phosphorus load delivered to Sylvan Lake before wetland development;

SYLVAN T.P. = total phosphorus (sediment-bound and dissolved) load delivered to Sylvan Lake before wetland development;

SYLVAN T.P. w/ WETLAND = total phosphorus load delivered to Sylvan Lake with wetland developed at proposed site which traps 80 percent of incoming sediments.

EFFECT OF WETLAND AT 800 NORTH ROAD (80 PERCENT TRAP EFFICIENCY ASSUMED)

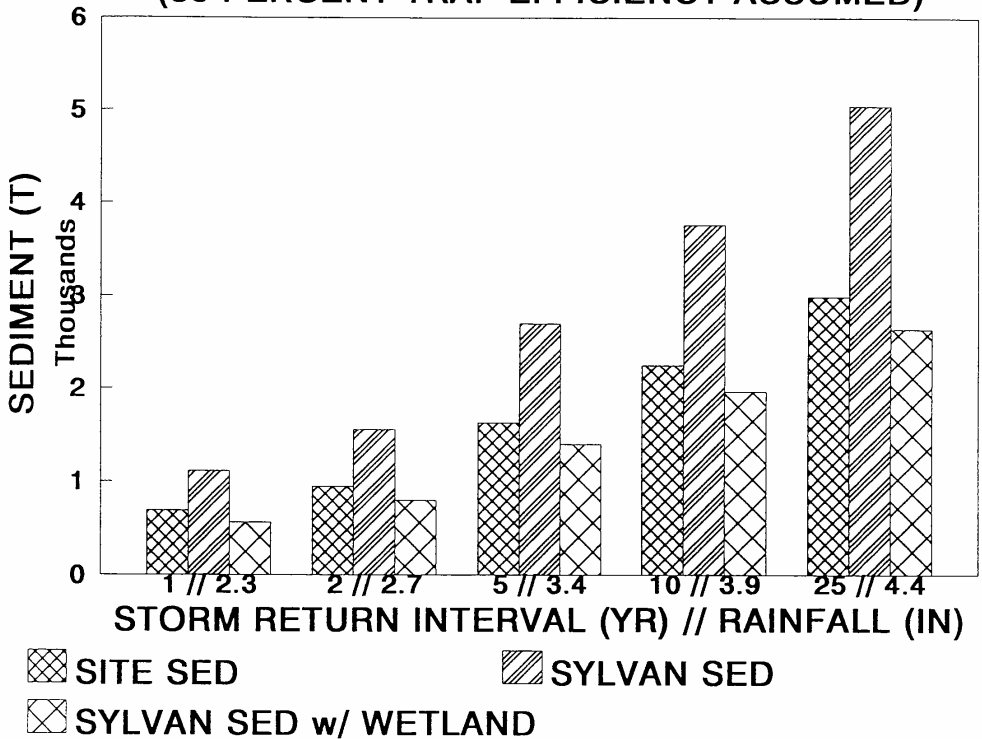


Figure 6c.

Potential changes in sediment loadings to Sylvan Lake due to construction of wetlands on Henderson Lake Ditch at 800 North Road where:

SITE SED = sediment load at proposed site;

SYLVAN SED = sediment load delivered to Sylvan Lake before wetland development;

SYLVAN SED w/ WETLAND = sediment load delivered to Sylvan Lake with wetland developed at proposed site which traps 80 percent of incoming sediments.

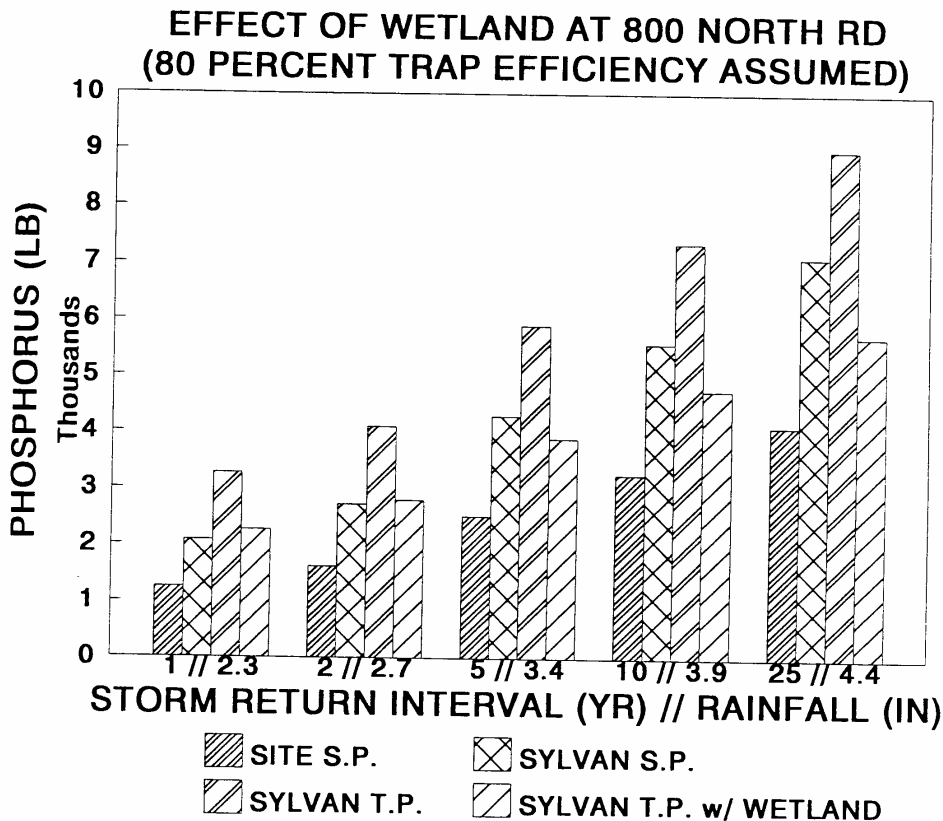


Figure 6d.

Potential changes in phosphorus loadings to Sylvan Lake due to construction of wetlands on Henderson Lake Ditch at 800 North Road where:

SITE S.P. = sediment-bound phosphorus load at proposed site;

SYLVAN S.P. = sediment-bound phosphorus load delivered to Sylvan Lake before wetland development;

SYLVAN T.P. = total phosphorus (sediment-bound and dissolved) load delivered to Sylvan Lake before wetland development;

SYLVAN T.P. w/ WETLAND = total phosphorus load delivered to Sylvan Lake with wetland developed at proposed site which traps 80 percent of incoming sediments.

APPENDIX A

SYLVAN LAKE IMPROVEMENT ASSOCIATION INDIANA DEPARTMENT OF NATURAL RESOURCES T by 2000 LAKE ENHANCEMENT PROGRAM	APPENDIX A-1 SYLVAN LAKE AGNPS RESULTS SUMMARY AND NON-POINT-SOURCE POLLUTION ROUTING	HARZA Engineering Company PROJ. No: 5256B DATE: APR 1991 FILE: Y01ROUTE.WK1
--	--	--

CASE: 1-YEAR, 24-HOUR STORM
RAINFALL = 2.3 INCHES
TYPE II-STORM ENERGY-INTENSITY VALUE = 29

SUB-WATERSHED			STORM RUN-OFF			SEDIMENT		DISSOLVED PHOSPHORUS			SEDIMENT PHOSPHORUS		
No.	TRIB. TO SUB-WATER SHED No.	AREA // AGNPS MODEL AREA (1) (AC)	STORM RUNOFF (2) (IN)	RUNOFF VOLUME (1)		SUBWATER-SHED (T)	TOTAL ROUTED (T)	RUN-OFF/ LAKE CONC. (PPM)	YIELD (1) (LB)	TOTAL ROUTED (LB)	YIELD (LB)	TOTAL ROUTED (LB)	
				SUBWATER-SHED (AC-FT)	TOTAL ROUTED (AC-FT)								
TOTAL		21660	—	955	955	—	1113			1187	—	2082	
BASIN:	1	SYLVAN LAKE (3)	2900	0.90	208	955	—	1113	0.38	215	1187	—	2082
		UPPER	—	—	—	—	76	1113				169	2082
		LOWER	—	—	—	—	16	1037				38	1912
		CAIN	—	—	—	—	38	1021				80	1874
		GRAVEL PIT	—	—	—	—	10	982				22	1795
	2	GRAVEL PIT BASIN	110	0.77	8	747	5	972	0.14	3	973	17	1772
			120										
	3	2	1610	0.50	67	67	— (4)	0	0.04	7	7	— (4)	0
	4	2	1140	0.44	31	161	125	125	0.83	69	80	227	227
			840										
	5	2	2910	0.50	88	511	542	842	1.14	272	883	903	1528
		2110											
6	4	3100	0.50	130	130	— (4)	0	0.03	11	11	— (4)	0	
7	5	810	0.48	26	147	164	164	0.92	64	71	283	283	
		640											
8	5	2780	0.59	134	276	136	136	1.45	527	539	342	342	
		2720											
9	7	690	0.50	29	122	— (4)	0	0.03	2	7	— (4)	0	
10	8	3390	0.50	142	142	— (4)	0	0.03	12	12	— (4)	0	
11	9	2220	0.50	93	93	— (4)	0	0.02	5	5	— (4)	0	

NOTES:

- (1) THE AGNPS MODEL COMPUTED AREAS WHICH DO NOT COUNT AREAS CONTRIBUTING TO SINK HOLES; RUNOFF VOLUMES AND DISSOLVED PHOSPHORUS LOADINGS WERE DETERMINED FROM AGNPS AREAS WHERE AVAILABLE.
- (2) RUNOFF WAS COMPUTED BY AGNPS MODEL FOR SUB-WATERSHEDS 1, 2, 4, 5, 7, AND 8; RUNOFF FOR OTHER SUB-WATERSHEDS WAS DETERMINED FROM AVERAGE RUN-OFF OF Nos. 4, 5, 7, AND 8.
- (3) SYLVAN LAKE WATERSHED AREA INCLUDES LAKE SURFACE AREA (669 ACRES) AND RUNOFF INCLUDES RAINFALL FALLING ON LAKE SURFACE.
- (4) AREAS UPSTREAM OF LAKES ARE ASSUMED TO CONTRIBUTE NO SEDIMENT TO CHANNELS DOWNSTREAM DUE TO TRAPPING CAPACITY OF LAKES.

SYLVAN LAKE IMPROVEMENT ASSOCIATION INDIANA DEPARTMENT OF NATURAL RESOURCES T by 2000 LAKE ENHANCEMENT PROGRAM						APPENDIX A-2 SYLVAN LAKE AGNPS RESULTS SUMMARY AND NON-POINT-SOURCE POLLUTION ROUTING				HARZA Engineering Company PROJ. No: 5256B DATE: APR 1991 FILE: Y02ROUT.WK1			
CASE: 2-YEAR, 24-HOUR STORM RAINFALL = 2.7 INCHES TYPE II-STORM ENERGY-INTENSITY VALUE = 39													
SUB-WATERSHED			STORM RUN-OFF			SEDIMENT		DISSOLVED PHOSPHORUS			SEDIMENT PHOSPHORUS		
No.	TRIB. TO SUB- WATER SHED No.	AREA // AGNPS MODEL AREA (1) (AC)	STORM RUNOFF (2) (IN)	RUNOFF VOLUME (1)		SUBWATER- SHED (T)	TOTAL ROUTED (T)	RUN-OFF/ LAKE CONC. (PPM)	YIELD (1) (LB)	TOTAL ROUTED (LB)	YIELD (LB)	TOTAL ROUTED (LB)	
				SUBWATER- SHED (AC-FT)	TOTAL ROUTED (AC-FT)								
TOTAL		21660	---	1328	1328	---	1551			1366	---	2724	
BASIN:	1 SYLVAN LAKE (3)	2900 2770	1.15	265	1328	---	1551	0.33	238	1366	---	2724	
	UPPER	---	---	---	---	114	1551				229	2724	
	LOWER	---	---	---	---	24	1437				53	2495	
	CAIN	---	---	---	---	56	1413				109	2442	
	GRAVEL PIT	---	---	---	---	15	1357				30	2334	
2	GRAVEL PIT BASIN	110 120	1.03	10	1063	7	1342	0.12	3	1128	20	2304	
3	2	1610	0.72	96	96	---	0	0.04	10	10	---	0	
						(4)					(4)		
4	2	1140 840	0.65	46	231	172	172	0.64	79	94	292	292	
5	2	2910 2110	0.72	127	725	751	1164	0.92	317	1020	1182	1991	
6	4	3100	0.72	185	185	---	0	0.03	15	15	---	0	
						(4)					(4)		
7	5	810 640	0.68	36	210	222	222	0.76	75	85	364	364	
8	5	2780 2720	0.82	186	389	191	191	1.18	601	618	445	445	
9	7	690	0.72	41	174	---	0	0.03	3	11	---	0	
						(4)					(4)		
10	8	3390	0.72	203	203	---	0	0.03	17	17	---	0	
						(4)					(4)		
11	9	2220	0.72	133	133	---	0	0.02	7	7	---	0	
						(4)					(4)		

NOTES:
(1) THE AGNPS MODEL COMPUTED AREAS WHICH DO NOT COUNT AREAS CONTRIBUTING TO SINK HOLES; RUNOFF VOLUMES AND DISSOLVED PHOSPHORUS LOADINGS WERE DETERMINED FROM AGNPS AREAS WHERE AVAILABLE
(2) RUNOFF WAS COMPUTED BY AGNPS MODEL FOR SUB-WATERSHEDS 1, 2, 4, 5, 7, AND 8; RUNOFF FOR OTHER SUB-WATERSHEDS WAS DETERMINED FROM AVERAGE RUN-OFF OF Nos. 4, 5, 7, AND 8.
(3) SYLVAN LAKE WATERSHED AREA INCLUDES LAKE SURFACE AREA (669 ACRES) AND RUNOFF INCLUDES RAINFALL FALLING ON LAKE SURFACE.
(4) AREAS UPSTREAM OF LAKES ARE ASSUMED TO CONTRIBUTE NO SEDIMENT TO CHANNELS DOWNSTREAM DUE TO TRAPPING CAPACITY OF LAKES.

SYLVAN LAKE IMPROVEMENT ASSOCIATION INDIANA DEPARTMENT OF NATURAL RESOURCES T by 2000 LAKE ENHANCEMENT PROGRAM	APPENDIX A-3 SYLVAN LAKE AGNPS RESULTS SUMMARY AND NON-POINT-SOURCE POLLUTION ROUTING				HARZA Engineering Company		
					PROJ. No: 5256B		
					DATE: APR 1991		
					FILE: Y05ROUTE.WK1		

CASE: 5-YEAR, 24-HOUR STORM
RAINFALL = 3.4 INCHES
TYPE II-STORM ENERGY-INTENSITY VALUE = 65

SUB-WATERSHED			STORM RUN-OFF			SEDIMENT		DISSOLVED PHOSPHORUS			SEDIMENT PHOSPHORUS	
No.	TRIB. TO SUB-WATER SHED No.	AREA // AGNPS MODEL AREA (1) (AC)	STORM RUNOFF (2) (IN)	RUNOFF VOLUME (1)		SUBWATER-SHED (T)	TOTAL ROUTED (T)	RUN-OFF/ LAKE CONC. (PPM)	YIELD (1) (LB)	TOTAL ROUTED (LB)	YIELD (LB)	TOTAL ROUTED (LB)
				SUBWATER-SHED (AC-FT)	TOTAL ROUTED (AC-FT)							
TOTAL		21660	—	2055	2055	—	2698			1622	—	4277
BASIN:	1 SYLVAN LAKE (3)	2900 2770	1.63	376	2055	—	2698	0.27	276	1622	—	4277
	UPPER	—	—	—	—	204	2698				373	4277
	LOWER	—	—	—	—	43	2494				85	3905
	CAIN	—	—	—	—	106	2451				185	3820
	GRAVEL PIT	—	—	—	—	27	2345				47	3635
	2 GRAVEL PIT BASIN	110 120	1.54	15	1679	10	2318	0.10	4	1346	27	3588
	3 2	1610	1.14	153	153	— (4)	0	0.04	17	17	— (4)	0
	4 2	1140 840	1.06	74	368	296	296	0.43	87	111	458	458
	5 2	2910 2110	1.14	200	1143	1296	2013	0.68	370	1215	1841	3103
	6 4	3100	1.14	294	294	— (4)	0	0.03	24	24	— (4)	0
	7 5	810 640	1.08	58	333	373	373	0.57	89	106	553	553
	8 5	2780 2720	1.27	288	609	344	344	0.91	712	738	709	709
	9 7	690	1.14	65	276	— (4)	0	0.03	5	17	— (4)	0
	10 8	3390	1.14	321	321	— (4)	0	0.03	26	26	— (4)	0
	11 9	2220	1.14	210	210	— (4)	0	0.02	11	11	— (4)	0

NOTES:

- (1) THE AGNPS MODEL COMPUTED AREAS WHICH DO NOT COUNT AREAS CONTRIBUTING TO SINK HOLES; RUNOFF VOLUMES AND DISSOLVED PHOSPHORUS LOADINGS WERE DETERMINED FROM AGNPS AREAS WHERE AVAILABLE.
- (2) RUNOFF WAS COMPUTED BY AGNPS MODEL FOR SUB-WATERSHEDS 1, 2, 4, 5, 7, AND 8; RUNOFF FOR OTHER SUB-WATERSHEDS WAS DETERMINED FROM AVERAGE RUN-OFF OF Nos. 4, 5, 7, AND 8.
- (3) SYLVAN LAKE WATERSHED AREA INCLUDES LAKE SURFACE AREA (669 ACRES) AND RUNOFF INCLUDES RAINFALL FALLING ON LAKE SURFACE.
- (4) AREAS UPSTREAM OF LAKES ARE ASSUMED TO CONTRIBUTE NO SEDIMENT TO CHANNELS DOWNSTREAM DUE TO TRAPPING CAPACITY OF LAKES.

SYLVAN LAKE IMPROVEMENT ASSOCIATION INDIANA DEPARTMENT OF NATURAL RESOURCES T BY 2000 LAKE ENHANCEMENT PROGRAM						APPENDIX A-4 SYLVAN LAKE AGNPS RESULTS SUMMARY AND NON-POINT-SOURCE POLLUTION ROUTING				HARZA Engineering Company PROJ. No: 5256B DATE: APR 1991 FILE: Y10ROUTE WK1			
CASE: 10-YEAR, 24-HOUR STORM RAINFALL = 3.9 INCHES TYPE II-STORM ENERGY-INTENSITY VALUE = 88													
SUB-WATERSHED			STORM RUN-OFF			SEDIMENT		DISSOLVED PHOSPHORUS			SEDIMENT PHOSPHORUS		
No.	TRIB. TO SUB-WATER SHED No.	AREA // AGNPS MODEL AREA (1) (AC)	STORM RUNOFF (2) (IN)	RUNOFF VOLUME (1)		SUBWATER-SHED (T)	TOTAL ROUTED (T)	RUN-OFF/ LAKE CONC. (PPM)	YIELD (1) (LB)	TOTAL ROUTED (LB)	YIELD (LB)	TOTAL ROUTED (LB)	
				SUBWATER-SHED (AC-FT)	TOTAL ROUTED (AC-FT)								
TOTAL		21660	—	2632	2632	—	3757			1765	—	5581	
BASIN:	1 SYLVAN LAKE (3)	2900 2770	2.00	462	2632	—	3757	0.23	289	1765	—	5581	
	UPPER	—	—	—	—	294	3757				497	5581	
	LOWER	—	—	—	—	61	3462				110	5085	
	CAIN	—	—	—	—	153	3402				250	4974	
	GRAVEL PIT	—	—	—	—	38	3249				63	4724	
2	GRAVEL PIT BASIN	110 120	1.93	19	2170	13	3211	0.09	5	1477	33	4661	
3	2	1610	1.47	198	198	— (4)	0	0.04	21	21	— (4)	0	
4	2	1140 840	1.39	97	478	411	411	0.35	93	124	602	602	
5	2	2910 2110	1.47	258	1476	1789	2788	0.57	400	1327	2383	4026	
6	4	3100	1.47	380	380	— (4)	0	0.03	31	31	— (4)	0	
7	5	810 640	1.40	75	432	507	507	0.48	97	119	709	709	
8	5	2780 2720	1.63	369	785	492	492	0.77	773	807	934	934	
9	7	690	1.47	85	357	— (4)	0	0.03	7	22	— (4)	0	
10	8	3390	1.47	416	416	— (4)	0	0.03	34	34	— (4)	0	
11	9	2220	1.47	272	272	— (4)	0	0.02	15	15	— (4)	0	

NOTES:

(1) THE AGNPS MODEL COMPUTED AREAS WHICH DO NOT COUNT AREAS CONTRIBUTING TO SINK HOLES; RUNOFF VOLUMES AND DISSOLVED PHOSPHORUS LOADINGS WERE DETERMINED FROM AGNPS AREAS WHERE AVAILABLE.

(2) RUNOFF WAS COMPUTED BY AGNPS MODEL FOR SUB-WATERSHEDS 1, 2, 4, 5, 7, AND 8; RUNOFF FOR OTHER SUB-WATERSHEDS WAS DETERMINED FROM AVERAGE RUN-OFF OF Nos. 4, 5, 7, AND 8.

(3) SYLVAN LAKE WATERSHED AREA INCLUDES LAKE SURFACE AREA (669 ACRES) AND RUNOFF INCLUDES RAINFALL FALLING ON LAKE SURFACE.

(4) AREAS UPSTREAM OF LAKES ARE ASSUMED TO CONTRIBUTE NO SEDIMENT TO CHANNELS DOWNSTREAM DUE TO TRAPPING CAPACITY OF LAKES.

SYLVAN LAKE IMPROVEMENT ASSOCIATION INDIANA DEPARTMENT OF NATURAL RESOURCES T by 2001 LAKE ENHANCEMENT PROGRAM				APPENDIX A-5 SYLVAN LAKE AGNPS RESULTS SUMMARY AND NON-POINT-SOURCE POLLUTION ROUTING				HARZA Engineering Company PROJ. No: 5256B DATE: APR 1991 FILE: Y25ROUTE.WK1				
CASE: 25-YEAR, 24-HOUR STORM RAINFALL = 4.4 INCHES TYPE II-STORM ENERGY-INTENSITY VALUE = 115												
SUB-WATERSHED			STORM RUN-OFF			SEDIMENT		DISSOLVED PHOSPHORUS			SEDIMENT PHOSPHORUS	
No.	TRIB. TO SUB-WATER SHED No.	AREA // AGNPS MODEL AREA (1) (AC)	STORM RUNOFF (2) (IN)	RUNOFF VOLUME (1)		SUBWATER-SHED (T)	TOTAL ROUTED (T)	RUN-OFF/ LAKE CONC. (PPM)	YIELD (1) (LB)	TOTAL ROUTED (LB)	YIELD (LB)	TOTAL ROUTED (LB)
				SUBWATER-SHED (AC-FT)	TOTAL ROUTED (AC-FT)							
TOTAL		21660	—	3234	3234	—	5031			1905	—	7073
BASIN:	1	SYLVAN LAKE (3) 2900 2770	2.39	552	3234	—	5031	0.21	315	1905	—	7073
		UPPER — — — —				406	5031				643	7073
		LOWER — — — —				82	4828				140	6430
		CAIN — — — —				210	4544				300	6290
		GRAVEL PIT — — — —				51	4334				79	5990
	2	GRAVEL PIT BASIN 110 120	2.33	23	2682	16	4282	0.08	5	1590	39	5910
	3	2 1610	1.82	245	245	— (4)	0	0.04	27	27	— (4)	0
	4	2 1140 840	1.74	122	593	548	548	0.29	96	134	762	762
	5	2 2910 2110	1.83	322	1822	2376	3719	0.49	429	1424	3020	5110
	6	4 3100	1.82	471	471	— (4)	0	0.03	38	38	— (4)	0
	7	5 810 640	1.73	92	534	666	666	0.42	105	132	888	888
8	5 2780 2720	1.99	451	966	677	677	0.67	821	863	1201	1201	
9	7 690	1.82	105	442	— (4)	0	0.03	9	27	— (4)	0	
10	8 3390	1.82	515	515	— (4)	0	0.03	42	42	— (4)	0	
11	9 2220	1.82	337	337	— (4)	0	0.02	18	18	— (4)	0	

NOTES:
(1) THE AGNPS MODEL COMPUTED AREAS WHICH DO NOT COUNT AREAS CONTRIBUTING TO SINK HOLES; RUNOFF VOLUMES AND DISSOLVED PHOSPHORUS LOADINGS WERE DETERMINED FROM AGNPS AREAS WHERE AVAILABLE.
(2) RUNOFF WAS COMPUTED BY AGNPS MODEL FOR SUB-WATERSHEDS 1, 2, 4, 5, 7, AND 8; RUNOFF FOR OTHER SUB-WATERSHEDS WAS DETERMINED FROM AVERAGE RUN-OFF OF Nos. 4, 5, 7, AND 8.
(3) SYLVAN LAKE WATERSHED AREA INCLUDES LAKE SURFACE AREA (669 ACRES) AND RUNOFF INCLUDES RAINFALL FALLING ON LAKE SURFACE.
(4) AREAS UPSTREAM OF LAKES ARE ASSUMED TO CONTRIBUTE NO SEDIMENT TO CHANNELS DOWNSTREAM DUE TO TRAPPING CAPACITY OF LAKES.